Space Technology Research Grants

A LIBS Boroscope for Evaluation of Mars Sample Return Core Candidates

Completed Technology Project (2013 - 2017)

Project Introduction

The leading recommendation of the Decadal Survey [National Research Council, 2011] is &taking the first critical steps toward returning carefully selected samples from the surface of Mars. This research program will develop a laser-induced breakdown spectroscopy (LIBS) boroscope for performing stratigraphic analyses of the walls of boreholes left by a sampling corer or drill like those envisioned for a Mars sample return (MSR) mission. The primary purpose of an MSR mission is to bring samples to Earth, where they can be examined using the most sophisticated scientific methods. Because returning samples is difficult, proposed MSR mission architectures budget just 350 - 500 g for specimens. In order to reconcile the conflicting requirements of sample diversity and limited payload, the makeup of collected materials should be measured before they are cached. Depth-profiled measurements of the borehole left by the corer or drill after the sample is extracted will yield insight about a sample's strata, which can be used to confirm or reject its suitability. The LIBS boroscope described here can perform such measurements, which will yield geochemical context for specimens while also enabling scientists to evaluate physiochemical changes that might occur during cache or return. LIBS works by irradiating a sample, in this case the borehole wall, with a pulsed laser to induce plasma ignition and ablation. The continuum and line spectra from the plasma spark are used to identify elemental composition and, using standard spectroscopic practices, constrain the molecular makeup. Of the available instruments, laser-induced breakdown spectroscopy represents one of the best methods for rapidly characterizing a wide variety of geological materials and has suitable spatial resolution, depth profiling, and sample preparation requirements to be used in borehole mapping. The present study will focus on two main objectives: improving the pulse-to-pulse repeatability of LIBS measurements and developing a self-contained prototype LIBS boroscope instrument for technology-readiness-level maturation. With conventional LIBS instruments, detection limits are typically at the ppm or ppb level, but the pulse-to-pulse variance is typically on the order of 5 - 20 percent. To improve this, Phase I of the investigation will focus on implementing double-pulse excitation, time-resolved line-ratio measurements, as well as magnetic confinement and helium dousing. Between these techniques, this study seeks to reduce pulse-to-pulse variance by an order of magnitude. Finite element modeling of spark plasma evolution will be conducted alongside breadboard experiments to quantify improvements. The optimal inter-pulse delay, laser fluence ratio, helium douse rate, magnetic field energy ratio, and other results from the Phase I study will be used to inform design of the prototype instrument during Phase II. System engineering of the prototype will be anchored by existing or projected space technologies with respect to the double-pulse laser, spectrometer, and robotic mechanism controlling the optical probe. The anticipated outcomes of the LIBS boroscope investigation include improved repeatability for LIBS instruments designed for space and a proof of concept for this new measurement approach. Based on favorable laboratory results, flight implementation of a LIBS boroscope for an

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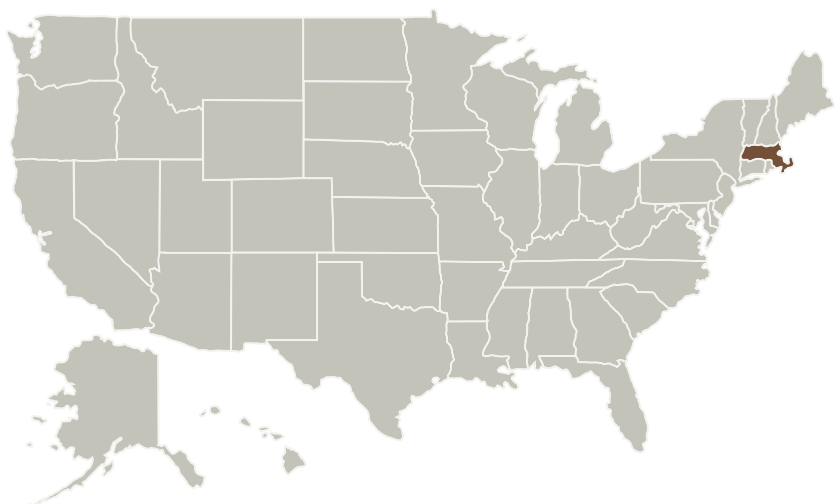
MSR mission could mitigate risks inherent to sample return and also yield scientific benefits that add value to procured specimens. Additionally, the fellowship investigation will enable the applicant to pursue his goal of working in space instrument development.

Anticipated Benefits

The anticipated outcomes of the laser-induced breakdown spectroscopy (LIBS) boroscope investigation include improved repeatability for LIBS instruments designed for space and a proof of concept for this new measurement approach. Based on favorable laboratory results, flight implementation of a LIBS boroscope for a Mars Sample Return mission could mitigate risks inherent to sample return and also yield scientific benefits that add value to procured specimens.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Harvard University	Lead Organization	Academia	Petersham, Massachusetts

Primary U.S. Work Locations
Massachusetts

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Harvard University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Eric Mazur

Co-Investigator:

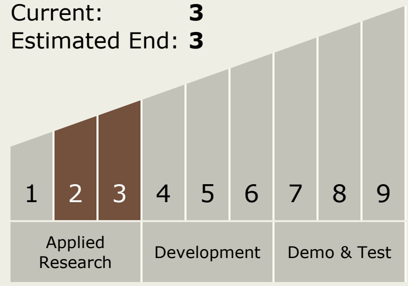
Alexander W Raymond

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.3 In-Situ Instruments and Sensors
    └ TX08.3.3 Sample Handling

Target Destination

Mars